KNOWLEDGE

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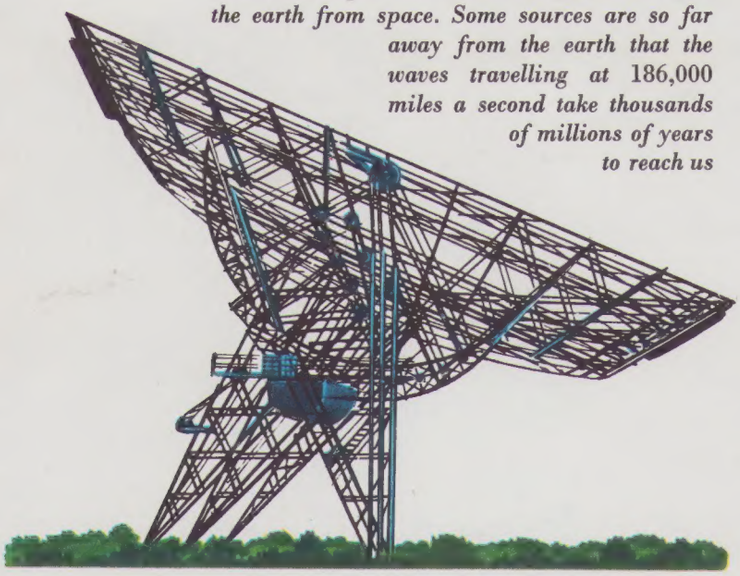
E ELECTROMAGNETIC WAVES (part two)



A large radio telescope near Nancy in France. Radio telescopes detect radio waves which reach the earth from space. Some sources are so far away from the earth that the waves travelling at 186,000 miles a second take thousands of millions of years to reach us

THE spectrum of electromagnetic waves is so vast that many types of instrument are needed to detect and use the waves in the different parts of this spectrum.

Radio waves and microwaves (24 octaves)

The first man-made source of radio waves was the spark transmitter invented by Hertz. This transmitter was not very powerful and could only be used for sending messages as dots and dashes (as in Morse Code). When the electronic valve was invented by Fleming in 1904 it became possible to transmit speech and music using radiofrequency waves.

Long waves (19 miles to half a mile in wavelength) are used for radio telegraphy and certain radio programmes. The B B C Light Programme wavelength is 1,500 metres or about one mile. These waves, on the whole, remain in the denser regions of the atmosphere so that the waves tend to follow the curved surface of the earth. For this reason they can be transmitted over quite long distances. Long waves are usually emitted in all directions by the aerial; it is very difficult to send them only in one direction. This means that a radio receiver a long way off will only intercept a very small amount of the energy sent out by the transmitter. So the transmitter must be as powerful as possible.

Medium waves (half a mile to 100 yards) also tend to keep to the earth's surface to some extent. These wavelengths are used by most European radio stations.

Short waves (100 yards to 10 yards) and very short waves (10 yards to 1 yard) travel in straight lines from the transmitting aerial and show no tendency to follow the curvature of the earth. Short waves are used in communication between continents, even from one side of the earth to the other. Of course if the waves continued to travel always in a straight line from the transmitter they would never reach the surface of the earth again. However, they are reflected back to the earth by two layers of the atmosphere called the 'E' and 'F' layers of the ionosphere. These consist of electrically charged atoms (*ions*) of gas. The 'E' layer is about 60 miles above the earth's surface and the 'F' layer lies between 125 and 300 miles high. Waves with longer wavelengths are reflected by the 'E' layer; waves with shorter wavelengths penetrate the 'E' layer and are reflected from the 'F' layer. When the wavelength is shorter than about 5 or 6 yards there is very little reflection back to earth from the ionosphere and most of the energy in the wave escapes into space. Radio messages can be sent by short waves over tremendous distances. It is possible to detect waves that have travelled several times around the world in a series of reflections from the ionosphere and the earth's surface.

The layers of the ionosphere are not at rest; they change their intensity and height between night and day and are also affected by particles emitted by the sun. This makes short-wave transmissions liable to fading. When there is an exceptionally large sunspot on the sun the number of particles reaching the earth is many times greater than normal. The ionosphere is so disturbed by this increase that short-wave radio communication is impossible. This is called a radio blackout. Since the ionosphere will let waves of wavelength less than a few yards escape into space, it will also let radio waves of wavelengths from a few yards to a few tenths of an inch reach the earth from space. The sun, the planet Jupiter, the

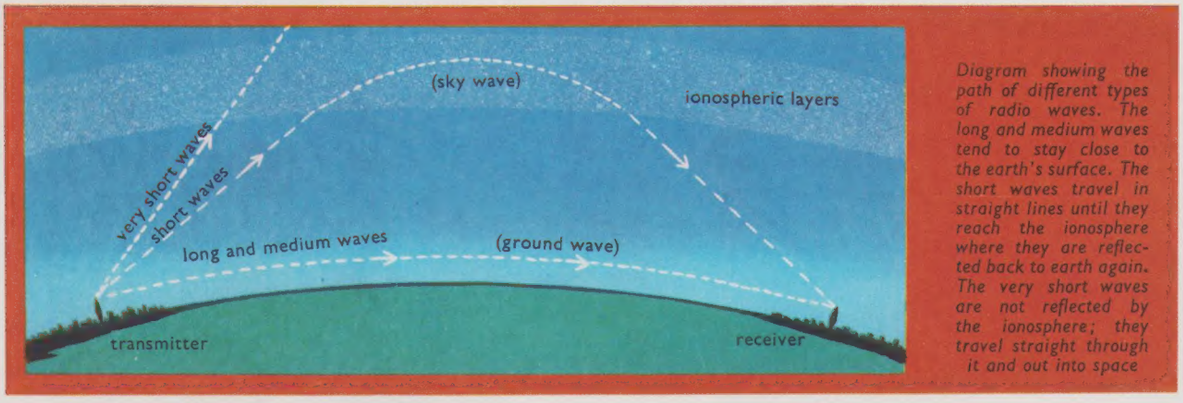


Diagram showing the path of different types of radio waves. The long and medium waves tend to stay close to the earth's surface. The short waves travel in straight lines until they reach the ionosphere where they are reflected back to earth again. The very short waves are not reflected by the ionosphere; they travel straight through it and out into space

Previous page: An artificial satellite is used to relay television pictures from one continent to another. The signals are beamed from a transmitting station to the satellite; the satellite amplifies the signals and retransmits them to a receiving station several thousand miles from the original transmitter.

Two 19th-century orchid collectors at work in the tropical South American forest

ORCHIDS

MANY people think that orchids, which are found in most parts of the world, are the most interesting and exciting of all plants. Their fantastic beauty had already started to attract the attention of wealthy people about the beginning of the last century, and to meet the demand, collectors made perilous journeys into the tropical forests, where orchids reach their greatest development.

These early orchid hunters were hardy men and ran great risks. No wonder that they asked high prices for the orchids they managed to bring home from the Amazon or the interior of Borneo. Sometimes £1,000 was paid for a plant of a hitherto unknown species.

These tropical orchids can be grown in temperate countries if they are kept in glass houses and given the right conditions of warmth and humidity. But at first only plants actually brought from the tropics could be grown, as all attempts to propagate the seeds failed. This was partly because the particular insects which pollinate the orchids in their native forests were lacking, and partly because the tiny, dust-like seeds of orchids require very special conditions to germinate.

The first difficulty was met by artificial pollination, and close study of the plants led to methods of growing them from seed. All orchids have a certain kind of fungus growing in their roots, and cannot live without it. Normally the seeds require the presence of this fungus in order to germinate and grow, and it must be supplied from the roots of the mother plant. This is called the *symbiotic* method, and was discovered in 1904 by a French botanist. Later an American scientist found a way to grow orchid seeds without fungus. He used sterilised jelly supplied with sugar and soluble plant foods, rather as cultures of bacteria are grown. This *asymbiotic* method is the one most often used today.

A botanist using apparatus in the asymbiotic method of cultivating orchids

THREE TYPES OF PLANT

All orchids are perennial herbaceous plants and live for a number of years, sometimes even for a century or more. They can be classified into three types according to how they grow.

Ground orchids grow in the soil. Practically all the orchids of temperate regions belong to this type.

Epiphytic orchids are those which grow on the trunks and branches of trees. They are not parasites as they obtain no nourishment from the living tissues of the 'host' tree. Their roots are generally of two kinds: clasping roots, which anchor them to the host, and aerial roots. These hang in the air and absorb moisture from it. Epiphytic orchids can only grow in very humid conditions and are mainly found high up in the trees of rain forests.

Climbing orchids have their roots in the ground and climb up trees in the same way as ivy and creepers.

THE FLOWER

Orchids have many features of botanical interest, but they are cultivated and treasured on account of their extraordinary flowers. These are sometimes borne singly but more usually in clusters.

The flower has three or five large petal-like structures, two of which are true petals and the rest sepals. In addition it has a kind of lip called the *labellum*, which may be tube-like or trumpet-shaped, or formed like a shoe as in the 'lady's slipper' type of orchid. Besides being beautifully coloured, many orchids are fantastically shaped and many resemble insects. This has led to the names of such species as the bee orchid and butterfly orchid.

Many orchid flowers have complicated devices connected with their pollination which is almost always carried out by insects.

Cypripedium venustum

20,000 species

About 20,000 different species of orchids have been described and named by botanists; the Orchidaceae is, in fact, the largest plant Family in the world. The great majority come from the tropics; in Britain there are only about 50 wild species. Some of the more common tropical kinds that can be grown in greenhouses are shown on these two pages. They are generally spoken of by the botanical name of the genus.

CYPRIPEDIUM and the closely related *PAPHIOPEDILUM* and *SELENIPEDIUM* are the 'lady's slipper' orchids. They are found mainly in Asia.

CATTLEYA. The flowers are among the largest and finest of natural orchids. All the species are epiphytic and are found in South and Central America.

LAELIA is closely related to *Cattleya* and is found in the same region. The orchids of these two genera can be hybridised and some really magnificent flowers have been obtained in this way. The hybrids are named *LAELIOCATTLEYA*. There are probably not many more spectacular wild orchids to be discovered, but by cross-pollination and the asymbiotic method of germinating seeds horticulturists can 'create' an almost infinite variety of new orchids.

CYMBIDIUM. These orchids are found over a wide area, from Madagascar to Asia and Australia. Most of them are ground orchids, and are popular because they flower profusely and the flowers often last for weeks.

ODONTONIA is the name given to hybrids between the natural genera *ODONTOGLOSSUM* and *MILTONIA*.

VANDA. These large plants, with broad-petalled pink or blue flowers, are natives of Asia. The one illustrated, *Vanda caerulea*, is called the 'blue moon orchid'.

ANGRAECUM. These are epiphytic species which are found in tropical Africa and Madagascar, and are among the few 'greenhouse' orchids coming from that region.

ARACHNIS is the name of the curious scorpion orchids which come from tropical Asia. The two plants on the far right are European orchids, and one of them, *Cypripedium calceolus*, occurs as a great rarity in Britain.

Paphiopedilum insigne

Laeliocattleya

Laeliocattleya

Odontonia

Cymbidium
Laeliocattleya
Selenipedium grande
Cymbidium
Nigritella nigra
Arachnis
Angraecum superbum
Vanda caerulea
Cypripedium calceolus

CIVIL SERVICE IN BRITAIN

ALL around us civil servants are carrying out their jobs. The postman delivers the letters; in the Employment Exchange the staff help people to find jobs; inspectors check on factories and schools. All these people, and many others, are civil servants. Their earnings may be below £6 a week, or over £7,000 a year; they may be highly qualified or without any special training at all.

What is it that all these different people have in common? They are servants of the Crown whose salaries or wages are paid directly out of money voted by Parliament; who are not holders of political or judicial office; and who are employed in a civil, as distinct from a military or naval, capacity.

Civil servants and politicians

At first sight it seems easy to confuse civil servants with politicians, especially as both are involved in governing the country, but there are outstanding differences. Civil servants make up the *permanent* staff of government departments, and are organised on a completely non-party basis; while politicians are members of political parties who are elected by the people and who do not permanently hold their positions. The government, which is made up of politicians, decides new policies; the work involved in carrying them out is done by civil servants in the government departments.

Each department is headed by a minister, who is a member of the government, and when there is a change of government there is also a change of minister. Under him is a permanent secretary; he is a civil servant and, as his name suggests, he is not affected by changes of government. His experience and advice are invaluable to the minister. The titles of the heads of departments vary, but their functions are basically the same. The various branches of the department are staffed by members of the different Civil Service grades; they too are permanent and not affected by changes of government.

The permanence of the Civil Service in Britain provides a valuable continuity in the running of the country. In many other countries a change of government also means a change of senior civil servants, which makes it more difficult for the administration of the country to be carried out smoothly during, and immediately after, a parliamentary election.

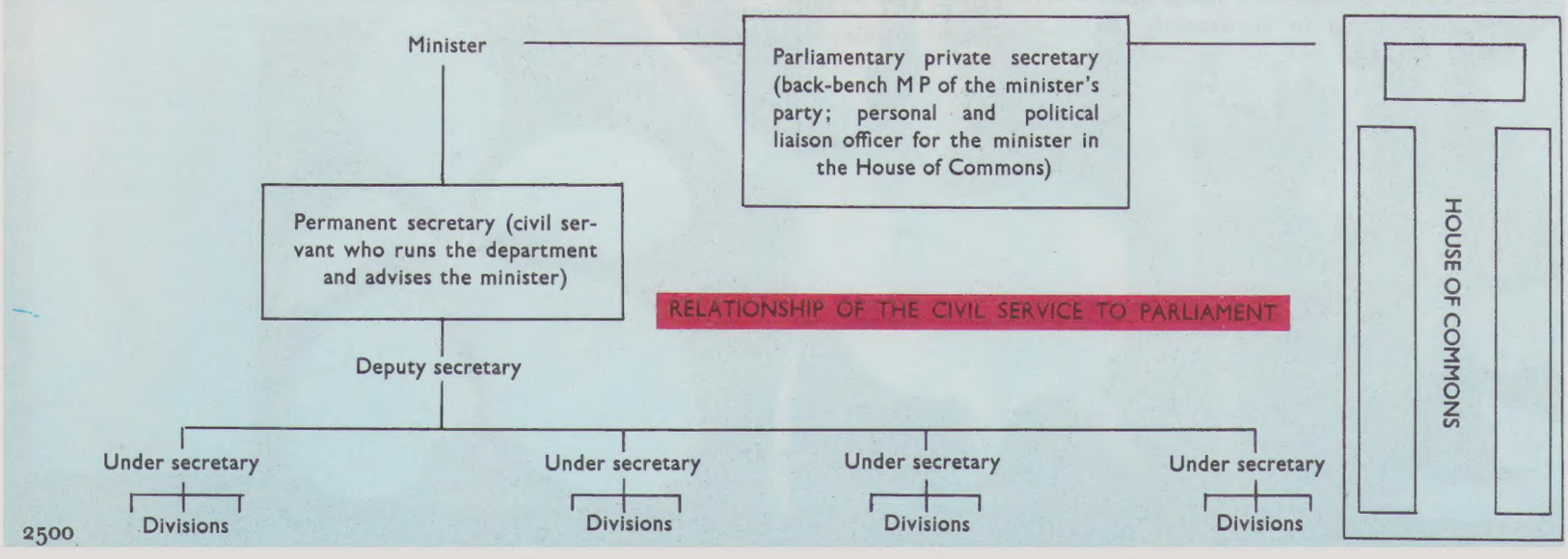
Some of the many government departments are shown in the diagram below. Chief of them is the Treasury, which has powers of supervision and regulation over the other departments – over the amount of money they spend, the way in which they spend it, and the number of staff they employ. The Treasury has two joint permanent secretaries, and one of them is the official head of the Home Civil Service (the Foreign Service is a separate self-contained service of the Crown). But as well as staffing these departments, civil servants are found in many unexpected organisations not directly under ministers. All of them are connected in some way or other with the well-being of the country, but they include such different things as the National Agricultural Advisory Service, the British Museum, the Road Research Laboratory, and the Central Office of Information.

The structure of the Civil Service

In the mid-19th century Civil Service appointments were often openly given to unqualified relations or friends of the heads of departments, or were obtained by purchase. But in 1854 a famous report was presented by Sir Stafford Northcote and Sir Charles Trevelyan. The essence of their proposals was that entry into the Civil Service should be by means of a written examination, and that staff should be recruited through a single central body and should be interchangeable between different departments. The Civil Service Commission was set up the following year, and is still responsible for recruiting all permanent civil servants.

Recruitment to the Civil Service and promotion within it are now determined by merit, and the various departments have a standardised salary structure. There are examinations for some posts and interviews for other types of job; in both, qualifications and experience are taken into account (some posts require an examination as well as an interview).

The Civil Service is now divided into classes, each with a series of grades; it is possible to be promoted from one class to another. The highest is the *Administrative Class*, which advises ministers on policy, deals with difficulties arising from current policy, and forecasts the effects of current policy. This class once consisted entirely of people with university degrees and upper-class backgrounds; today a number of its members have been promoted from the class below and new entrants with degrees have not necessarily got the traditional background. The *Executive Class* is responsible for the day-to-day running of government business, carrying out within the framework of established policy work requiring judgement and initiative. The *Clerical Class* undertakes all the clerical work of departmental business, such as the keeping of records and preparation of accounts, and handles certain claims in accordance with strict rules. The


Minister
Parliamentary private secretary (back-bench M P of the minister's party; personal and political liaison officer for the minister in the House of Commons)
Permanent secretary (civil servant who runs the department and advises the minister)
Deputy secretary
Under secretary
Under secretary
Under secretary
Under secretary
Divisions
Divisions
Divisions
Divisions
HOUSE OF COMMONS

RELATIONSHIP OF THE CIVIL SERVICE TO PARLIAMENT

Professional, Scientific, and *Technical Classes* include such skilled men as architects, doctors, lawyers, and engineers; they range from ministers' senior advisers on technical matters to junior draughtsmen and scientific assistants. Then there are the *Ancillary Clerical Classes*, including typists and machine operators; *Messengerial and Minor Classes*, including messengers, paper keepers, and office cleaners; and *Departmental Classes*, including specialised jobs like postmen, telephonists, and inspectors.

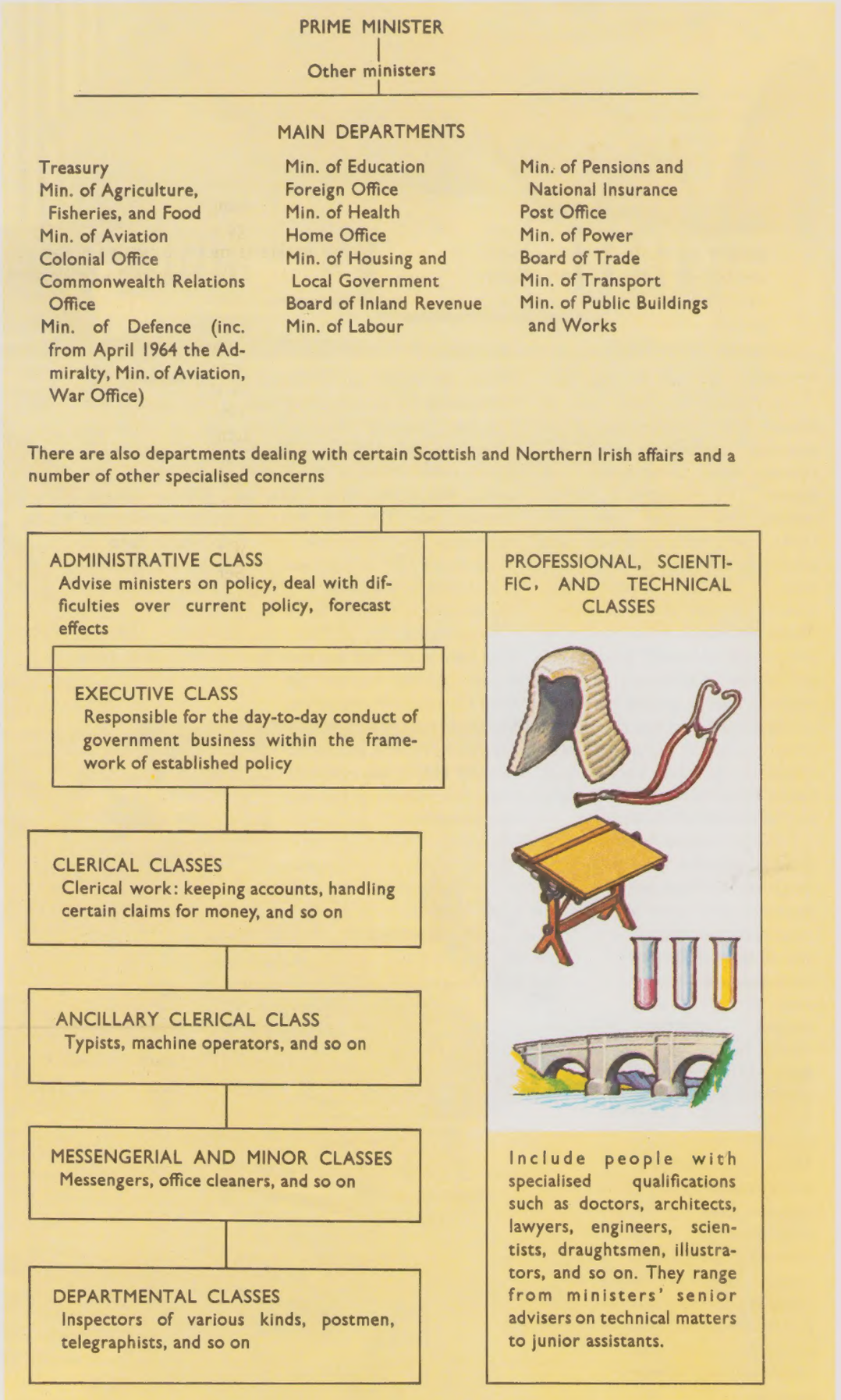
Too large an organisation?

The danger in so large an organisation is of *bureaucracy*. A man sends in a claim for money to a government department. A clerical officer handles it and, correctly applying the established rules, refuses it. But the senior officers who drew up the rules had not envisaged this man's particular circumstances. The man feels he has been treated unjustly, and that the clerical officer with whom he is dealing is remote from the senior officers with the authority to deal with unusual circumstances. He wonders if he will ever obtain what he hopes for.

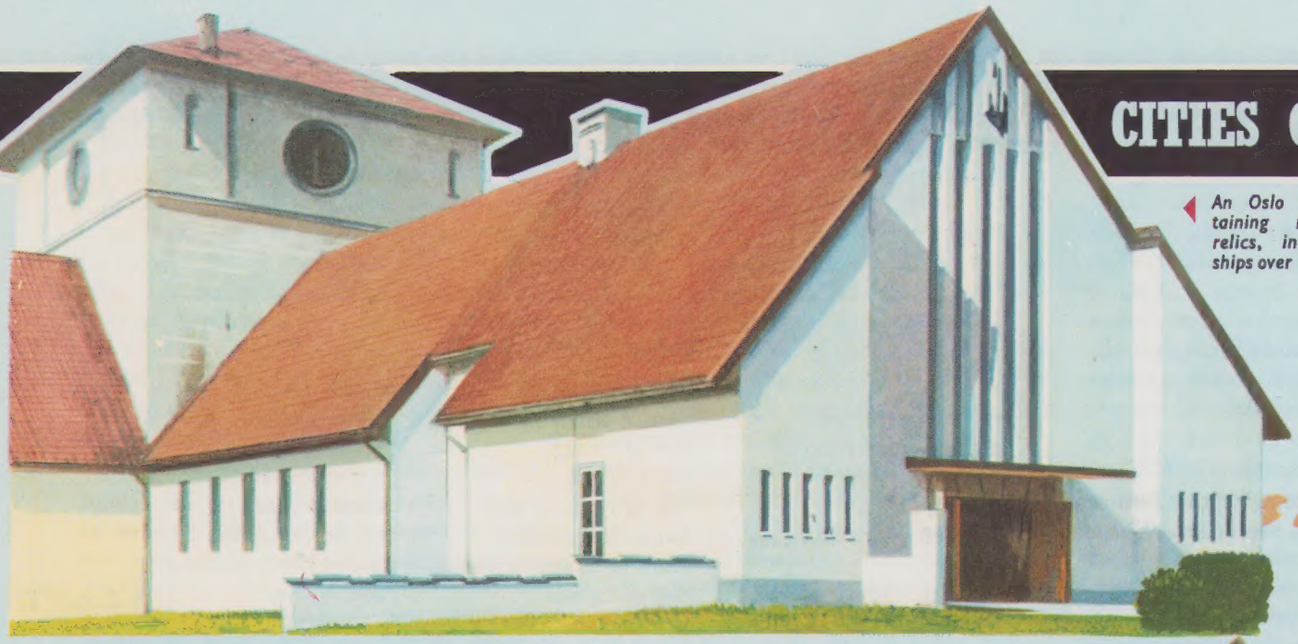
There is no complete answer to this problem. If we are to be sure that civil servants do not casually make up different rules in different parts of the country – and do not anywhere make up rules contrary to the intention of Parliament – we must be prepared for delay in getting special treatment for special cases.

If the citizen is not satisfied with the treatment of his case he can contact his Member of Parliament, who, if he thinks there is a genuine grievance, will then approach the appropriate minister. He may write to the minister, who will pass the letter to his department, where it will be looked into. The minister will then explain to the M P why the original request was refused, or if there has been some error he will see that it is put right. In some cases the M P will put a question to the minister in Parliament. On rare occasions when there has been serious negligence of a citizen's rights, the minister may even resign – even if he knew nothing of what was going on. According to the principle of *ministerial responsibility*, he should have known.

This principle does sometimes result in injustice to individual ministers, who cannot in practice know what all their staff of thousands are doing all the time. But the knowledge that their minister may have to account for their actions to Parliament encourages civil servants to behave legally and considerately, and to seek guidance from the people above them in difficult cases – and in exceptionally tricky matters to approach the minister. Ministerial responsibility is the greatest safeguard against bureaucracy. Insistence on it is the same as saying that justice for the humblest citizen is every bit as important as justice for ministers of the Crown.


PRIME MINISTER
Other ministers
MAIN DEPARTMENTS
Treasury
Min. of Agriculture, Fisheries, and Food
Min. of Aviation
Colonial Office
Commonwealth Relations Office
Min. of Defence (inc. from April 1964 the Admiralty, Min. of Aviation, War Office)
Min. of Education
Foreign Office
Min. of Health
Home Office
Min. of Housing and Local Government
Board of Inland Revenue
Min. of Labour
Min. of Pensions and National Insurance
Post Office
Min. of Power
Board of Trade
Min. of Transport
Min. of Public Buildings and Works
There are also departments dealing with certain Scottish and Northern Irish affairs and a number of other specialised concerns
ADMINISTRATIVE CLASS
Advise ministers on policy, deal with difficulties over current policy, forecast effects
EXECUTIVE CLASS
Responsible for the day-to-day conduct of government business within the framework of established policy
CLERICAL CLASSES
Clerical work: keeping accounts, handling certain claims for money, and so on
ANCILLARY CLERICAL CLASS
Typists, machine operators, and so on
MESSENGERIAL AND MINOR CLASSES
Messengers, office cleaners, and so on
DEPARTMENTAL CLASSES
Inspectors of various kinds, postmen, telegraphists, and so on
PROFESSIONAL, SCIENTIFIC, AND TECHNICAL CLASSES
Include people with specialised qualifications such as doctors, architects, lawyers, engineers, scientists, draughtsmen, illustrators, and so on. They range from ministers' senior advisers on technical matters to junior assistants.

CITIES OF NORWAY



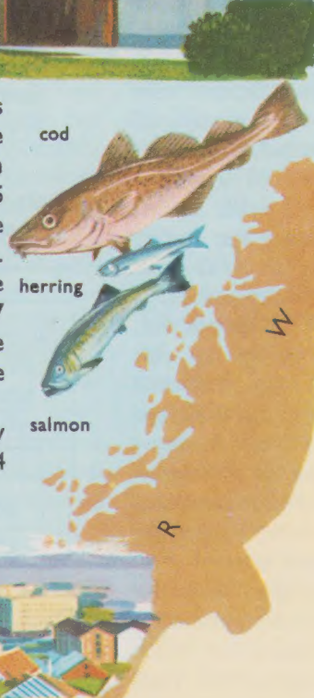
An Oslo Museum containing many Viking relics, including three ships over 1,000 years old

TOWNS are not so important in Norway as they are in Britain. This is because many of the economic conditions which encourage their development are absent. The country is mountainous and rugged (see page 1644), and communications are extremely difficult. Moreover, very little of the land is productive; under 3 per cent of it is cultivated. These difficulties have prevented the growth of a large population; and indeed the density of Norway's 3½ million people (under 30 per square mile) is less than in any other country in Europe. Norway therefore has never needed large towns to act as centres of supply in the interior of the country.

Things would be different if there were huge industrial resources; but Norway lacks both coal and oil. She is rich in hydro-electricity and this is used for developing certain industries – chiefly steel. Yet the basis of Norwegian economy remains as it always has been – timber and fish. These are exported in vast quantities, and the revenue used to import the many things Norway lacks. For this reason virtually all Norway's important towns are ports – and along the coast such industries as Norway possesses (like canning) have developed.

OSLO, the capital and principal port of Norway, lies surrounded by pine-wooded hills at the head of the Oslo fjord, some 80 miles from the open sea. Although it has a population of only about 477,000, its area of 175 square miles makes it the fourth largest city in the world. But unlike most cities, Oslo grew overnight. On New Year's Day, 1948, the authorities extended the city limits in all directions and Oslo found itself 27 times larger than it had been the day before. Because of this eccentric pattern of growth 75 per cent of the city of Oslo is covered by fields and forests.

The original city of Oslo was founded in 1050 by King Harold III. This was destroyed by fire, and in 1624 a new city was founded by King Christian IV and called Christiania. This became the capital city in 1814, and on 1st January 1925 it was renamed Oslo. Very little of the old city remains.



A Norwegian man in national costume

cod

herring

salmon

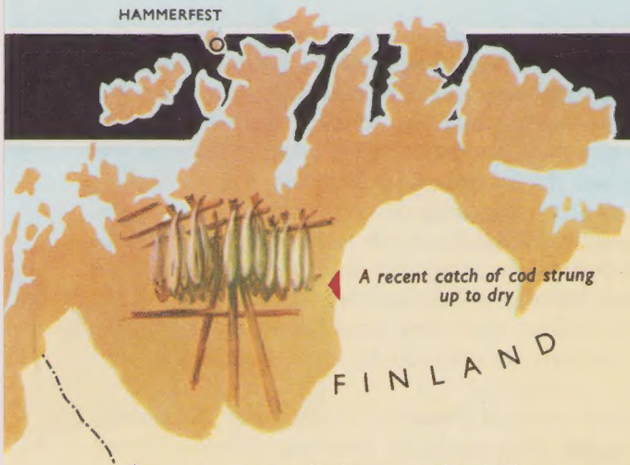
Trondheim, once the capital

fishing boat

Bergen – Norway's second city

Fish canning

Oslo's City Hall, completed in 1950 and decorated by Norway's leading sculptors and painters



A recent catch of cod strung up to dry

One interesting building is the 14th-century Akershus Castle which was used as the German headquarters during their occupation in the Second World War.

Oslo's wide range of industries include shipbuilding and the manufacture of electrical equipment and machinery. Its merchant shipping in 1957 had a gross tonnage of over 3,000,000 tons, about 40 per cent of the country's total.

BERGEN, the second largest city in Norway (population 116,000), in no way regards itself as inferior to Oslo, for until the 1830s it had a larger population and it was an important commercial and military centre when Oslo was still little more than a village.

The original town was founded in 1070. It grew rapidly and the Hanseatic merchants established their most northerly *Kontor* (trading community) here. Some of the buildings from the prosperous 15th and 16th centuries still survive; one of these is now the remarkable Hanseatic Museum. Fire has been a great enemy of Bergen, and after 1916 the present series of broad streets was constructed to help guard against further fires. The central harbour is a busy place with its famous fish market only yards away from where the fishing vessels dock.

TRONDHEIM was the capital city of Norway until 1380, but it then went into a decline which lasted until the present century. Recently, however, it has prospered and today has a population of 59,000. It was founded in 996 by Olav Tryggvasson, the first Christian king of Norway. The cathedral of Trondheim is the Gothic masterpiece of Norway; the town also has a bishop's palace, a relic of the mediaeval days when Trondheim had some 16 churches and two monasteries. Trondheim has a very mild climate and is an excellent winter sports centre. It also carries on a brisk trade in timber, wood pulp, oil, and fish, and is a shipbuilding town.

STAVANGER (population 53,000) lies on the western coast of Norway on the Bokn fjord, in the most fertile and heavily populated area of Norway. It was founded in the 8th or 9th century and is one of the oldest towns in Norway, but the greater part of the present town is modern and built of stone instead of wood. It has a very exciting history and many interesting survivals from the past, including the cathedral church of St Swithun, founded by an English bishop at the end of the 11th century.

The new Stavanger of modern buildings, bustling traffic, and great water-front factories has emerged from wealth brought by the humble sardine tin, for Stavanger is the fish-canning capital of the world and probably exports more canned foods than any other city.

Many Norwegian houses, particularly in the north, are made of wood

HAMMERFEST (population 6,000) is the most northerly town in Europe. It lies on the island of Kralöy, off the north-west coast of Norway, at a latitude of 71° north. The people of Hammerfest know only one day and one night; their day lasts from the beginning of May to the end of July and their night from the middle of November to the end of January. The months in between are spent in an eerie twilight. For this town is the heart of the 'Land of the Midnight Sun.' The long winter months are hard to endure – little wonder that the town had electric light as early as 1891.

Most of the houses are built of wood and are fairly modern, for Hammerfest had to be rebuilt after a fire in 1890. Despite its extreme latitude, which is the same as that of north Alaska, the warm westerly winds and the North Atlantic drift keep the average January temperature at only a little below freezing point, and the harbour is free of ice all the year round.

The town smells strongly of cod, and salted fish are an important export. Reindeer skins are also exported, and one of the traditional sights of the town is the annual swim of the tame reindeer across the strait to the mainland where they graze in summer.

OTHER IMPORTANT TOWNS

DRAMMEN (pop. 32,000), in the heart of richly forested country, has grown from a small fishing village into a large timber exporting centre.

NARVIK (pop. 13,500), the scene of two naval battles in 1940, is on the Ofot railway (the most northerly in Europe); it was built early this century.

KRISTIANSUND (pop. 28,000) was founded in the 17th century. In the 19th century trade with England brought prosperity; today it is still flourishing.

A Norwegian fishing fleet setting out

THE PERSIAN WARS (part two)

The land and sea routes followed by the Persians in the Second Persian War

THE Persians learned from the disaster of Marathon (see page 2476) that it was not easy to conquer the Greeks. Yet they found this difficult to understand, for Greece was not united; it consisted rather of dozens of independent city-states, jealous of their individual freedoms. But when faced with a threat to their collective freedom the Greeks were prepared to close their ranks, and so they now pitted all their intelligence and skill against the huge armies of Persia.

Bridge of boats

In 486 B C Xerxes succeeded his father Darius as King of the Persians. He made tremendous preparations for a fresh invasion of Greece. He decided to bridge the Hellespont (Dardanelles) to make the passage of a large army easier. The first bridge was destroyed by a storm; and after the King had (as he supposed) punished the water by having it flogged with 300 lashes and ordering a pair of fetters to be thrown into it, the Persians built a new bridge of boats. Two bridges were made: one, Herodotus tells us, of 360 ships lashed together, the other of 314; they were skilfully anchored to resist wind and currents, planks were laid across them, and brushwood inserted between the planks. And thus a bridge was formed across which a whole army could move. In 492 Darius's first expedition had been wrecked off Mount Athos; so this time a canal was dug across the isthmus behind Mount Athos so that the ships could sail along the coast.

In 481 Xerxes decided to attack; and in 480 he invaded Greece. He had collected an enormous army, the largest the Greeks had ever seen. Herodotus tells us that the land army alone numbered 1,700,000 men; but we probably ought to take at least one nought from this figure. Even so, it was formidable, and for once the Greeks presented a united front. But they could not agree on a strategy. They sent a force to Thermopylae, the narrow pass between the mountains and the sea across which any army marching down the coast had to come. But many of its leaders thought this too far north to provide an adequate resistance. The people of Sparta in particular wanted to fall back to the Isthmus of Corinth, and defend the Peloponnesus only. But the King of the Spartans, Leonidas, realised that they would lose many of their allies if they abandoned northern Greece. So he decided to defend the pass of Thermopylae.

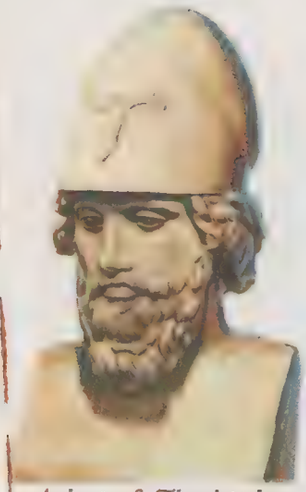
For several days wave after wave of Persians came against the Greeks guarding the narrow path. But they made no headway. Then a Greek traitor called Ephialtes went to Xerxes, and offered to show him a path

480 B C, *the battle of Salamis. Xerxes, King of the Persians, watches as ship after*

over the mountains by which his troops could take the Greeks in the rear. A picked force of Persian troops was sent over the mountain path by night and the Greeks found themselves hopelessly outmanœuvred. Leonidas had sent away most of his army, but he, together with a small Spartan force of 300 and a few others, held their ground. They fought heroically against the Persians, and inflicted great losses on them; eventually the Spartans retreated to a small hillock and fought until every one of them had been killed.

A naval battle saves Greece

After they had marched through the pass of Thermopylae, the Persians invaded Attica. They laid waste Athens and other cities. But the Athenians had been told by the Delphic oracle to defend their city 'with a wooden wall', and taking the advice of Themistocles they had interpreted this to mean a fleet of ships. The maps of the battle of Salamis on the left show how the Greek ships were anchored in a narrow strait where seamanship and knowledge of the shoals and the coastline counted far more than numbers. You can read in our article on Themistocles (see



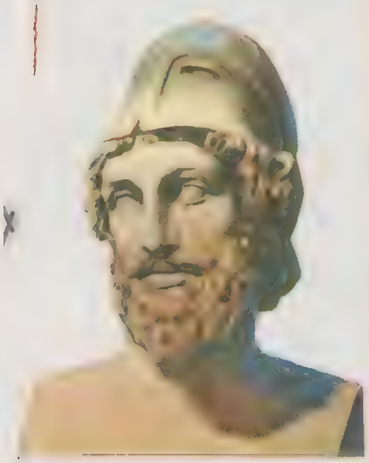
A bust of Themistocles – his 'wooden walls' smashed the Persian fleet

page 2223) that many of the Greeks wanted to move the fleet back to the Isthmus of Corinth, and how Themistocles eventually settled the argument by secretly advising the Persians to block the escape route the other side of the island. Both fleets prepared for action, and Xerxes took up a position on a hill on the mainland from which he could look across the straits towards the island of Salamis and watch how the battle went.

'The fleet had only just left the land,' writes Herodotus, 'when it was attacked by the barbarians. Most of the Greeks immediately began to back water, and were almost on shore again when Ameinias of Pallene, one of the Athenian captains, darted forward in front of the line and charged a ship of the enemy. The two ships became entangled and could not separate, and so the rest of the fleet came to the help of Ameinias, and the action was joined.' The Greeks had at most 380 ships; the Persians far more. But Greek discipline and seamanship were much better, and most of the Persian ships were put out of action.

The destruction of his fleet made Xerxes anxious about his lines of communication – tremendously important for the huge army he had brought. So he decided to retreat and leave the renewal of the attack to his general, Mardonius. Mardonius wintered in Thracia and Macedonia, and renewed the attack on Greece itself in the next year, 479.

ship of his great fleet is sunk by the Greeks

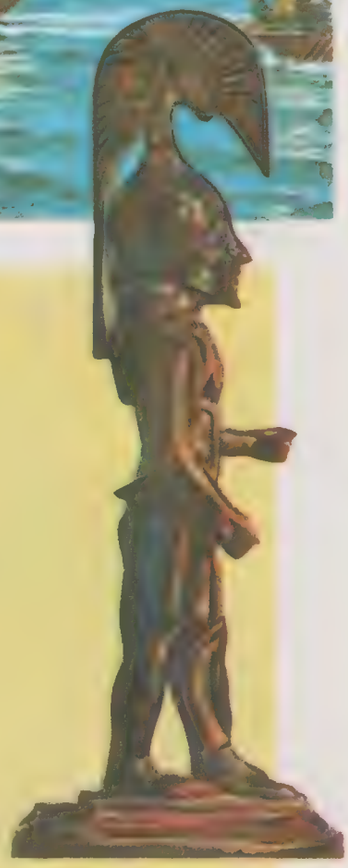


Bust of Leonidas – the hero of Thermopylae

FINAL GREEK VICTORY

Heartened by their victory at Salamis, the Greek cities put a large force into the field against Mardonius in the spring of 479. Although the Persian army was larger, the difference in numbers was nothing like so great as in the battles of 480. They fought near Plataea in Boeotia, and in a long and hotly contested pitched battle the Greeks were victorious and the Persian invasion was brought to an end.

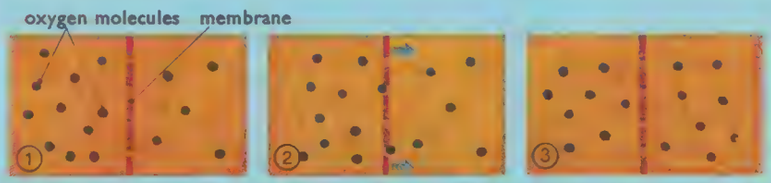
On the same day as the battle of Plataea, by a curious chance, the Persian fleet suffered another defeat; the Greeks took it by surprise at Mycale, near Miletus in Asia Minor, and destroyed it. Xerxes's attempt had been decisively thwarted and Greece was saved. The great Persian empire remained a threat for many years to come. Attacks on the Greek mainland were planned from time to time, but no invasion on the scale of that of 480 was mounted again; and although many Greek cities in Asia Minor continued subject to the Persians, Greece herself remained free.



Bronze of a Spartan soldier – these great crested helmets were to become dreaded by the Persians

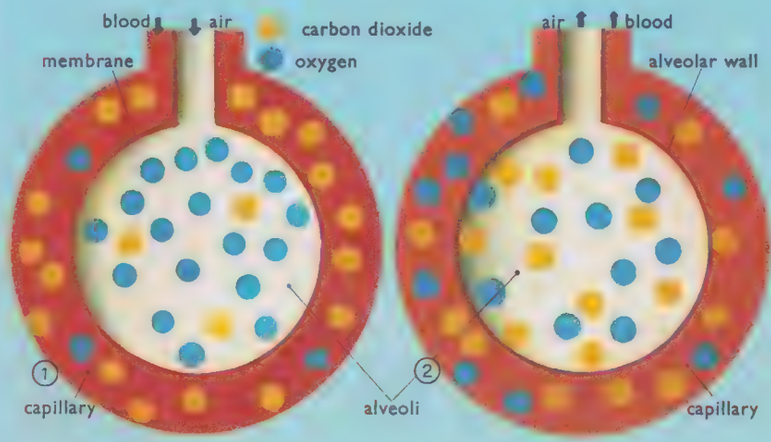
RESPIRATION (part two)

PART one of this article on page 2490 ended by stating that in the lungs the oxygen of the inspired air is transferred to the blood. Now we are going to look a little more closely at this wonderful process.



When air containing oxygen at different concentrations is separated by a membrane, the oxygen passes through the membrane until the concentrations are equalised

Imagine for a moment a glass chamber divided into two compartments by a membrane in which there are very many minute pores. The compartment on one side of the membrane is filled with air containing 20 per cent of oxygen, the compartment on the other side with air containing only 16 per cent of oxygen. The chamber is left overnight, and in the morning the concentrations of oxygen in the two compartments are measured. They are found to be the same. Some of the oxygen from the side with the greater oxygen concentration has passed through the pores in the membrane, reached the other compartment, and so equalised the oxygen concentrations on the two sides.

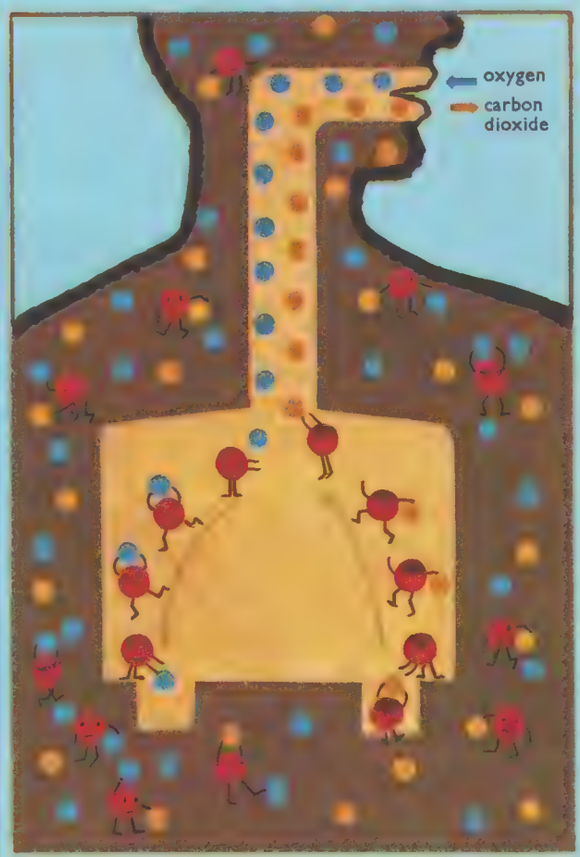


In the lungs the walls of the little air sacs, or *alveoli*, are very much like the membrane separating the two compartments of the glass chamber. On one side is the alveolar air to which oxygen is constantly added during respiration; on the other side are lung capillaries filled with blood laden with carbon dioxide. This is illustrated in the left-hand diagram, and is similar to stage ① of the glass chamber experiment. As in the chamber, the gases move to equalise the concentrations. Oxygen passes from the alveolar sacs into the blood, and carbon dioxide passes from the blood into the alveolar sacs until, as in the right-hand diagram, the concentrations are equal. As the respiratory movements constantly replace the oxygen in the alveoli, and as the heart is all the time pumping more blood laden with carbon dioxide through the lung capillaries, the process of gaseous change goes on continuously. In this way the blood is oxygenated, and unwanted and poisonous carbon dioxide removed from the body.

THE TRANSPORT OF OXYGEN

In the alveoli the oxygen is merely mixed with the other gases which form the alveolar air. Once it passes through the alveolar wall, however, the oxygen comes into contact with the haemoglobin contained in the red cells of the blood. It forms a loose complex with this substance called *oxyhaemoglobin*, and in this form oxygen is carried in the blood to all parts of the body.

When the oxyhaemoglobin-filled red cells reach an organ where the oxygen concentration is low, oxygen is released from the complex and enters the tissues. Here it is used up in the complicated processes of oxidation which provide the body with energy.



The oxygen in the alveoli is taken up by the red cells. At the same time the cells and the blood plasma give up their carbon dioxide, which escapes through the alveolar wall into the expired air

THE TRANSPORT OF CARBON DIOXIDE

As the oxygen is used up in the tissues an almost equal volume of carbon dioxide is produced. It escapes from the cells and finds its way into the blood in which it is carried to the lungs.

The way in which carbon dioxide is transported, however, is rather different from that of oxygen. Only about a fifth of the gas unites with haemoglobin to form a complex, in this case called *carbaminohaemoglobin*. By far the greater part dissolves in the blood plasma to form the salt sodium bicarbonate and is transported in this form to the lungs.

THE FALL OF NAPOLEON

THE awful heat of the Russian summer had given way to something even more terrible. After October the temperature fell rapidly, and soon the snows came. The men of the Grand Army, in full retreat, had never experienced such cold, and every day thousands fell from exhaustion. Guns dropped from frost-bitten fingers. The remaining horses were eaten and their blood was drunk or sucked as frozen wedges. . . . One of the great crossroads of history had been reached. The army of Napoleon, which people had thought unbeatable, was unquestionably beaten; and it was for its leader his first real set-back and the beginning of the end of his triumphal career.

Map showing the route of Napoleon's advance to and retreat from Moscow

In 1811, only a year before this disastrous retreat from Moscow, Napoleon had been at the height of his power. As we have seen on page 2491 he had subdued Europe. But he had not won its support. Europe's proud ruling families, the Romanovs of Russia, the Habsburgs of Austria, and the Hohenzollerns of Prussia, bitterly resented his triumphs over them. And there was another power whom Napoleon had never beaten – Britain, aloof and contemptuous, with an invincible navy, an army in Spain which was carrying all before it against Napoleon's generals, and a Treasury ready to finance Napoleon's enemies. In fact there was an increasing determination in Europe to defeat Napoleon, whatever the cost.

The first sign of trouble for Napoleon came from Russia. The Russians had been beaten at both Austerlitz and Friedland, but not decisively enough to endure the hardships imposed by Napoleon's continental blockade. And the Russian Tsar, Alexander I, was coming to believe that he was the 'strong man of the North' foretold by the Scriptures, who was to destroy 'Anti-Christ' whom he came to regard as Napoleon. Gradually, much to the undisguised fury of the French Emperor, certain Russian ports began admitting British ships under the cover of neutral flags, undermining his continental blockade.

Napoleon was determined to bring the Russians to heel, and so he prepared the Grand Army. And it *was* a grand army. Some half a million were assembled for the campaign. Less than half of them were French; the rest came from Spain, Prussia, Poland, Holland, Italy, and many other places. They had 150,000 horses, together with thousands of guns; wagons containing food and ammunition; and masses of equipment for building bridges to cross the many Russian rivers. Months before the campaign started Napoleon was poring over maps of Russia and studying past battles on Russian soil.

The Duke of Wellington acknowledges the cheers of his victorious troops after Waterloo. The British troops were the only ones who consistently got the better of Napoleon's armies, and they played a decisive part in his downfall

Under a leaden sky the French retreat from Moscow; tortured by bitter cold,

Then he began marching his army across Poland and massed it along the river Niemen. No word of conciliation came from the Tsar. On 23rd June the colossal army poured into Russia.

Napoleon knew perfectly well that the Russians would not willingly give battle. Yet he thought that as city after city fell the Russians would be forced either to make a stand to defend their homesteads or to submit. But he was tragically wrong. Occasionally a group of Cossacks would gaze down at the French army from the hills before turning their horses and cantering off towards the eastern horizon, but the Russian army remained aloof. Moreover, the people burned the land before the advancing army, and compelled the French to forage for food, which became increasingly scarce. When they entered Smolensk they found it scarcely habitable, for the Russians had left it a burning wreck. And although the campaign was as yet young the toll taken by the vast Russian plains and marshes was horrifying. Already, with scarcely a skirmish fought, Napoleon's army was reduced from 500,000 to 160,000.

Yet the cream of Napoleon's army was intact and he had no fear – if only the Russians could be brought to battle.

Map showing extent of Napoleon's German campaign of 1813

At last his hopes were fulfilled. As they left Smolensk and neared Moscow, with every mile destroying hundreds of men, the Russians decided to make a stand and try to save their sacred city.

The resulting battle was the battle of Borodino. Napoleon would have preferred to have fought with his army in better shape, but this was not a chance to be missed. Napoleon's strategy at Borodino was virtually non-existent. About 120,000 fought on each side, and both sides lost over 30,000. It was essentially a battle of individual commanders making individual decisions, with isolated acts of incredible heroism brightening a black and frightful day. For it was not enough to outmanœuvre the Russians. They had to be annihilated so that they could not withdraw and start the tantalising, elusive chase all over again. So, careless of men, Napoleon placed his faith in massed frontal assaults and in the end he carried the day. The Russians gave way and Napoleon pressed on to Moscow. At last he entered the city. He looked around for some herald or messenger to deliver its keys or acknowledge defeat, or at least seek an armistice. None came. Meanwhile the army, after its awful march, ran wild and rolled about the city in a longed-for orgy of drunkenness. The Russians had fired their precious city, but the French were in no fit state to put out the fires. Slowly building after building was consumed until one-third of the city was destroyed.

Then followed that terrible retreat from Moscow. As Napoleon's army staggered westwards they had to contend with two remorseless enemies: the bitter cold and the Russian armies which were now closing in. Soon a mere 40,000 men were nearing the river Beresina only to find that the bridge had fallen to the Russians. So, frantically, Napoleon's engineers set about building another. They worked up to their necks in freezing water with great blocks of ice driving down and sweeping them away or carrying off their work. On 26th November the bridge was ready and what was left of the army began to move. But the Russian armies had closed in and bombarded the scarcely moving French columns mercilessly. It took three days for the French army to cross, but the slaughter inflicted by the Russians was fantastic; no fewer than 24,000 French bodies, rigid from the cold, were washed up on the banks of the Beresina.

Napoleon undaunted

As his ramshackle army limped through Germany Napoleon detached himself from it and hurried to Paris. Once there his boundless confidence and infectious enthusiasm rallied the French to his side. Indeed the years between the retreat from Moscow and the battle of Waterloo were perhaps his most amazing years of all. Rapidly he gathered another army, lowering the recruiting age to 18 and the minimum height to 4 feet 9 inches. But abroad the news was bad. The sight of the remnants of the Grand Army decided the Prussians. They made an alliance with Russia and prepared for battle.

Napoleon was undaunted. His new army was inexperienced but he was still Europe's greatest general. A quick attack in the

unceasingly harassed by Cossacks, only a fraction of the Grand Army survived

following spring and the Russians would be punished, the Prussians crippled, and the Austrians frightened into remaining neutral. He began his offensive and marched through Germany with his raw recruits. On 2nd May (1813) he met the combined Russians and Prussians at Lützen, and in a battle in which he exposed himself recklessly to all the dangers of his men, the French emerged victorious. But this victory did not have the desired effect, for Austria was now ready to join the battle – against Napoleon. In August she joined the coalition of Russia, Prussia, and Britain (who had signed a treaty of alliance that June). Sweden too sent an army against Napoleon, and in Spain Wellington was reaching the climax of his successful Peninsular Campaign.

Napoleon on the defensive

Now at last the initiative lay with Napoleon's enemies. In August they attacked the French in Saxony and were driven back by Napoleon who brilliantly defeated Blücher of Prussia and Schwarzenberg of Austria at Bautzen and Dresden. The allies decided not to attack Napoleon in person, but to attack his subordinates. One by one, Vandamme, Macdonald, Oudinot, and Ney were defeated. Then at Leipzig the allies came face to face with the Emperor himself. This time their army of 300,000 triumphed over Napoleon's 190,000 in a terrible three-day battle. The Grand Duchy of Warsaw, Saxony, Bavaria, Hesse, Wurttemberg, Westphalia, and Berg renounced their allegiance to Napoleon; Holland revolted, and in January 1814 Napoleon lost Switzerland. His empire had collapsed like a house of cards.

The next step for the allies was the invasion of France, and in France hostility to the Emperor was understandably growing. Men refused to join his army, and they hid from recruiting officers. As the allies entered France Napoleon showed his old genius. His diminishing army won four battles in four days in the Departments of Aisne and Marne. But he could only postpone the inevitable. In March the British took Bordeaux. On 30th March the allies entered Paris. On 2nd April Napoleon heard that the Senate had deposed him. He wavered, but the army was behind the Senate. On 4th April he agreed to abdicate in favour of Louis XVIII. On 11th April the Treaty of Fontainebleau was signed. It decreed that Napoleon should renounce the rule of France and Spain and take up the sovereignty of the island of Elba.

The Hundred Days

Napoleon made one last attempt to recapture his kingdom. He escaped from Elba and in March 1815 landed in France. The army and much of the nation flocked to him; the Bourbons fled. But as you can read on page 2292, Wellington defeated Napoleon once and for all near the little Belgian village of Waterloo.

After Waterloo Napoleon realised that his cause was hopeless and surrendered to the British. But they showed him no mercy. He was exiled to the remote Atlantic island of St Helena, where he lived a further five and a half years in a closely guarded confinement – a shadow of the man who had ruled Europe.

NAPOLEON'S LEGACY

In the 18th century many European states had been like so many squares of a chessboard into which sovereigns moved their men as they pleased. Napoleon played this game on a more extensive scale than anyone. He reorganised Germany, which had been a patchwork of over 300 tiny marks, principalities, dukedoms, and bishoprics, as well as the larger states of Austria and Prussia, and reduced their number to 39. He abolished (in 1806) the meaningless title *Holy Roman Empire* and set up the *Confederation of the Rhine* which was completely subordinated to France. But this had unexpected results. For, under more centralised control, the Germans saw French domination for what it was – the rule of one people over another. They also saw that they had more in common with each other than with the French – language, race, culture, and territory. So they united in the face of their common foe. And the same thing happened all over Europe. Hatred of the French showed the people of Italy, Belgium, and Spain that they existed *as separate units*, and had the right to object to a rule they resented, whether of an alien conqueror or even their own despotic governments. So into the 19th century came a spirit of *Nationalism*, and, closely allied, *Liberalism*.

YOU SHOULD NOW KNOW

1. *How large was the Grand Army?*
2. *Why did Napoleon invade Russia?*
3. *Why did the invasion fail?*
4. *Name the five principal members of the coalition against Napoleon.*
5. *What were the Hundred Days?*

THE GIRAFFE

Drawing by Herr Melchior Lorch, one of the first Europeans to see a giraffe

IN the year 1559 a German traveller from Flensburg, Herr Melchior Lorch, visited Constantinople. The Sultan at that time lived in a luxurious palace with extensive gardens, in which a variety of animals was kept, and Herr Lorch was able to visit these gardens. When he returned home he wrote an account of his adventures and drew some of the animals in the Sultan's menagerie. Under the drawing which we show here he wrote: 'a particularly strange animal which none of us had ever seen before.' Quite clearly the animal was a giraffe, and Herr Lorch must have been one of the first Europeans ever to see one.

The first giraffe to be brought alive to Britain was presented to King George IV in 1827 by Mohammed Ali, Pasha of Egypt. A picture of it, with two Egyptian attendants and a top-hatted Englishman, hangs in the rooms of the Zoological Society of London.

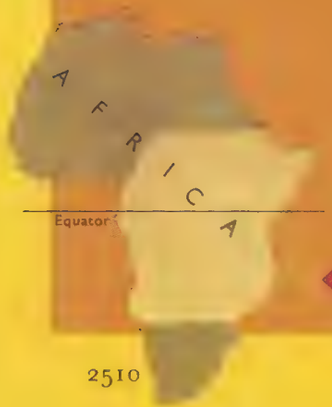
The word *giraffe* comes from the Arabic *zarafah*, meaning 'gentle' or 'amiable'; the animal was formerly called the camelopard, or the spotted camel.

CLASSIFICATION

The giraffe (*Giraffa camelopardis*) belongs to the Order of mammals called the Artiodactyla or even-toed hoofed mammals, which also includes pigs, deer, sheep, and oxen; and it is a ruminant – that is to say, it chews the cud. It is placed in the Family Giraffidae whose only other living member is the okapi, a rare animal which is regarded as a 'living fossil' (see page 2161).

WHERE THEY LIVE

Giraffes were once found all over Africa south of the Sahara. Today, however, they are no longer found in the southern tip of the continent, because they have been exterminated there. They live in open country or savannah where they feed on the foliage of the scattered trees. They are not found in forests, where their long legs and necks would hinder their movement.



The area of Africa in which giraffes are found

Both male and female giraffes have a pair of short, bony horns, covered with skin, on their heads. Some varieties have also a single small horn between the eyes

Their ears are rather large

Their nostrils are slit-like and can be closed at will

Their lips are adapted for grasping leaves, and their tongues are very long and are used for the same purpose

Their heads are narrow, with long muzzles

Their eyes are large and their sense of sight very keen

They have black manes on their necks

Their tails are 2 feet 6 inches long and end in black tassels

Their very long necks have seven vertebrae (like those of almost all mammals), but each vertebra is about 9 inches long

Their shoulders are very strong, and more powerfully developed than their hindquarters

Their forelegs are controlled by big strong muscles

Their legs are long and slender but strong; giraffes can run very fast

The giraffe's foot has a double or cloven hoof

FACTS ABOUT THE GIRAFFE

The giraffe is the tallest animal known; the top of its head may be as much as 18 feet above the ground. It is sometimes said to have no voice, but this is not true; it can make a bleating noise.

Measurements

The average weight is 1,100 lb

Skeleton of the giraffe: each neck vertebra is 9 inches long

HOW MANY KINDS?

We have spoken so far of 'the giraffe' as if only one kind existed. In a way this is so, because all giraffes are classified under one species, *Giraffa camelopardis*. They are, however, divided into several varieties or sub-species, which differ in various ways, especially in the shape of the large brown spots on the skin. There are two main types. The northern giraffes in Somalia and northern Kenya have spots with regular edges, divided by narrow white lines; this type is known as the reticulated giraffe. Those of the more southern regions also have a pattern of large spots on a pale background, but the spots have irregular borders and are often star-shaped; the Masai giraffe is one of the sub-species of this southern type.

The head of a young giraffe

HOW THEY LIVE

Giraffes are gregarious, living in small herds consisting of an old male, several females, and young of both sexes. They are often seen in company with other animals such as zebras and antelope and even ostriches. They feed almost entirely on the leaves of trees, especially acacia trees, gripping the foliage with their lips and tongues and biting it off with the teeth of their lower jaws.

They have a very keen sense of sight, which has probably developed in conjunction with their height, since this gives them a commanding view over a wide range of country. Their hearing is also acute and their ears can be turned back and forward to catch sound from any direction. They look awkward, but are capable of running at over 30 m p h. The gait of a giraffe is of the kind known as pacing, in which both legs of the same side are moved together. The camel also runs in this way.

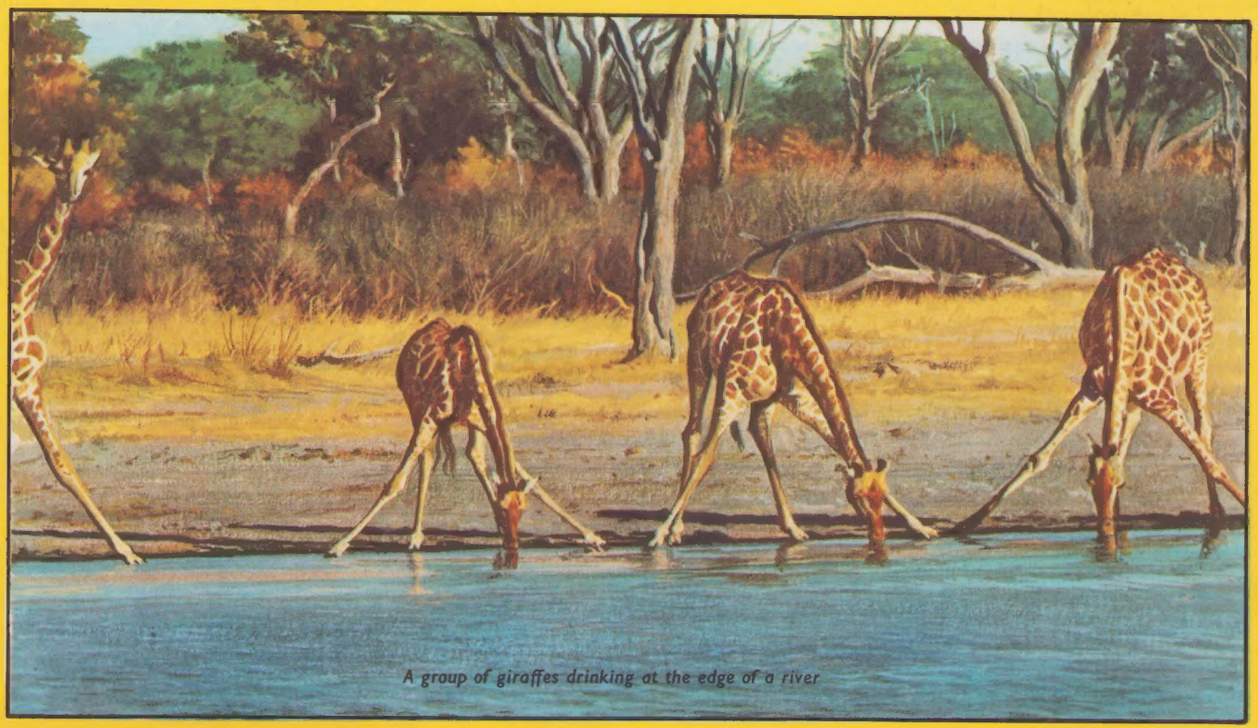
In order to drink (or to reach food on the ground) giraffes either straddle their forelegs wide apart or bend them at the knee-joints. They are able to go for long periods without drinking. Giraffes cannot swim and appear to dislike water; they do not seem to cross rivers, although they could obviously wade to a considerable depth if they wanted to.

Giraffes are gentle, inoffensive creatures, but in self-defence they can kick tremendously powerfully with their front legs; the leg is lifted and the hoof hurled forward like a battering ram. Lions prey on young giraffes, but the adults will fiercely defend their young as well as fighting very effectively on their own behalf. If a big giraffe drives one blow home it can kill a lion instantly.

FAMILY LIFE

Giraffes are usually born singly, though occasionally there are twins. A baby is about 6 feet long from head to tail when it is born. At first it follows its mother everywhere, but when there are several young ones in a herd they soon join each other to play. They also learn to reach up and bite off the tender shoots of the acacia trees. When they form a group in this way, one of the older females usually acts as nurse, looking after them and preventing them from straying into danger. No doubt the mothers take turns to perform this duty.

A giraffe is adult before it is a year old, and its life span is 25 to 30 years.

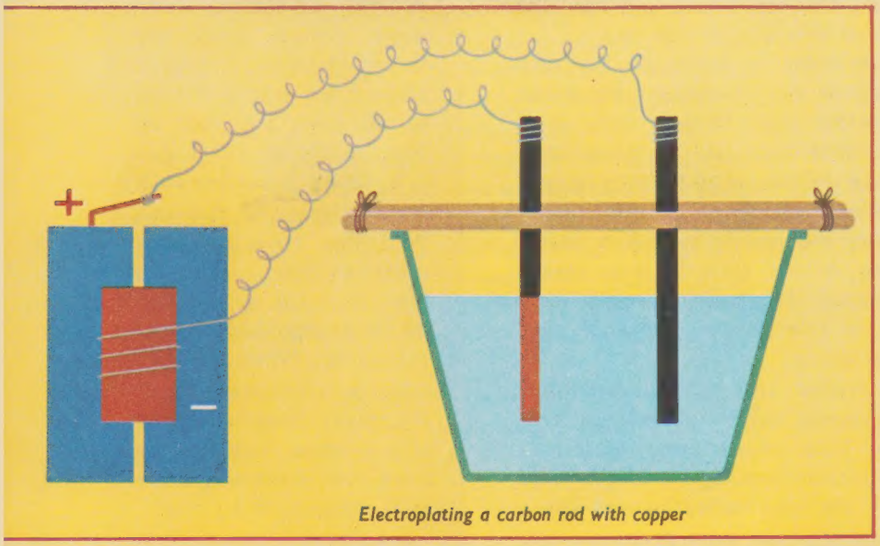


A group of giraffes drinking at the edge of a river

ELECTROLYSIS

HAVE you ever tried to split a molecule? Molecules are being split around you in nearly every chemical change that takes place (see page 30), and a very neat method of splitting molecules is *electrolysis*.

The atoms in a molecule are held together by electrical forces. They can be split apart by heat energy – for example, by roasting the substance in a furnace. But there is another way of splitting some molecules. When some substances are dissolved in water their molecules split into electrically charged atoms or groups of atoms called *ions*. For instance, common salt (NaCl) in water gives positively charged sodium ions (Na^+) and negatively charged chloride ions (Cl^-).



Electroplating a carbon rod with copper

Such substances are called electrolytes, and solutions of them in water will conduct electricity. When an electric current passes between two conductors immersed in such a solution the ions around the conductors may lose their charge and become neutral atoms which cannot stay in the solution. This process is known as *electrolysis*.

'DO IT YOURSELF' ELECTROLYSIS

Here are two simple experiments which need no special apparatus and which can safely be performed at home.

Copper plating. Make a plating bath in a small glass bowl by dissolving an ounce of copper sulphate in a quarter of a pint of water (*wash your hands after handling copper sulphate – it is poisonous*). Connect a carbon rod (from the centre of an old battery) to each terminal of a cycle-lamp battery with wire, making sure that the wires are held in good contact. Fasten the two carbon rods in position with two wooden strips held together with string or elastic bands as shown in the diagram. The rods conducting the electric current into the solution are called *electrodes*. Lower these electrodes (carbon rods) into the plating solution and it will soon be seen that one electrode is being copper plated. This is the electrode connected to the negative (zinc case) part of the battery; it is called the *cathode*, and the positive electrode is called the *anode*.

Positive copper ions from the solution lose their charge at the negative cathode to produce copper metal.

The electrolysis of water. Water is partly split into ions, and if there is no substance dissolved in the water which splits into ions that lose their charge more readily, the passage of an electric current will make the water ions themselves (H^+ and OH^-) lose their charges and become neutral. They are released as hydrogen and oxygen gases.

Pour a pint of water into a bowl and make it conductive by dissolving an ounce of washing soda in it. Fill two glass tubes (about 4 inches long by $\frac{1}{2}$ inch diameter) with this solution; hold the solution in with your thumbs and invert the tubes with their mouths below the surface of the solution in the bowl, and then take your thumbs away. Connect a 1-inch nail to each terminal of a cycle-lamp battery with plastic-covered copper wire. Cover the joint between the copper wire and the nail with candle grease, taking care to cover all the exposed copper wire but as little as possible of the nail.

The nails are to be our electrodes. Put one in the solution under each tube and you will notice that gas bubbles immediately start to form on the electrodes and the gas is collected in the tubes as shown in the diagram. It will soon be seen that there is twice as much gas collecting in the tube above the cathode as there is collecting in the tube above the anode.

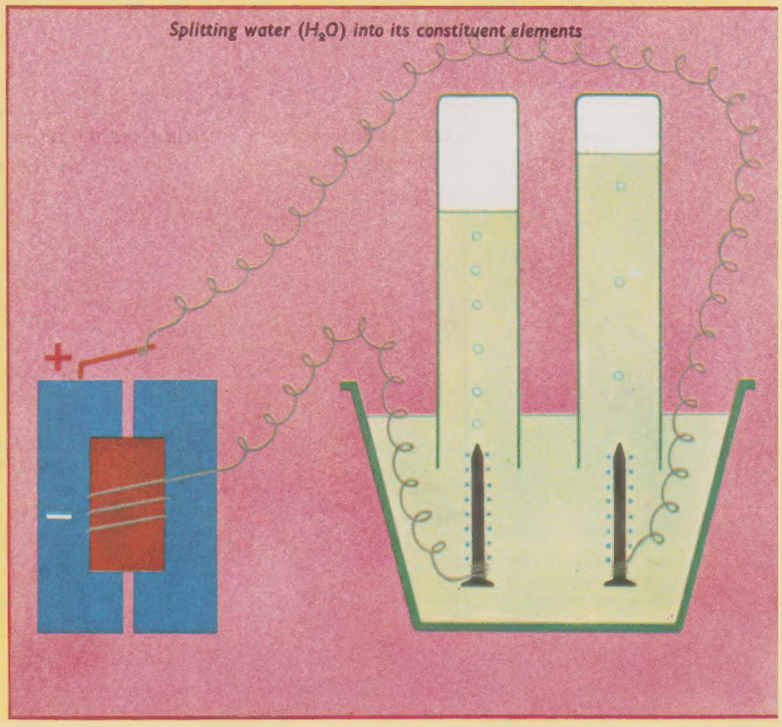
The gas collecting in the tube above the cathode is hydrogen; positive hydrogen ions (H^+) lose their charge at the negative cathode to give hydrogen atoms, which combine in pairs to give hydrogen gas molecules (H_2). The gas in the tube above the anode is oxygen; negative hydroxyl ions (OH^-) lose their charge at the positive anode and combine together to give oxygen gas and water ($4OH \rightarrow 2H_2O + O_2$).

Tests for hydrogen and oxygen. Hold a burning match to the mouth of the tube containing hydrogen. There will be a loud 'pop' as the hydrogen mixes with the air and burns.

Put a piece of smouldering string into the tube containing oxygen. At once the string will glow much more brightly and may even start to blaze. This is because when substances burn they combine with oxygen, and air is only one-fifth oxygen; so substances burn five times faster in pure oxygen than they do in air.

COMMERCIAL USE OF ELECTROLYSIS

Electrolysis is an important process in the chemical industry today. It can be used to prevent corrosion, to refine certain metals, and also to isolate such substances as aluminium and sodium. Electrolysis is also used to obtain hydrogen and oxygen for commercial use.



Splitting water (H_2O) into its constituent elements

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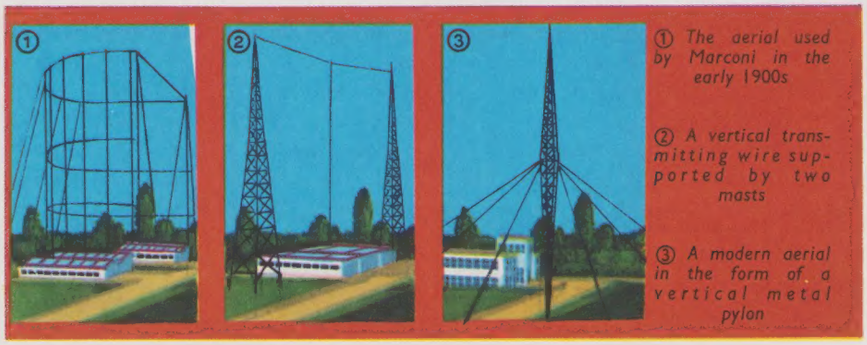
Milky Way, and many more objects in the Galaxy and beyond it all emit radio waves which can be picked up by radio telescopes. Radio waves are not absorbed as much as visible light waves by the giant dust clouds in the Universe. This allows the radio telescopes to penetrate further into space than optical telescopes.

Microwaves have wavelengths between about 10 yards and a twentieth of an inch. They include television and radar.

Television pictures are transmitted using very short waves (about 25 feet down to about 1 foot). The best reception of television occurs when there are no obstacles between the receiving aerial on the roof of a house and the transmitting mast. Since the waves are so short, they are easily absorbed or reflected from obstacles such as hills or tall buildings which lie in their path; and as television waves travel in a straight line and cannot be made to follow the curvature of the earth the range of most television stations is only 150 to 200 miles. It is possible to relay television pictures from one station to another using *microwave links*. Waves of wavelength of about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3
① The aerial used by Marconi in the early 1900s
② A vertical transmitting wire supported by two masts
③ A modern aerial in the form of a vertical metal pylon

Three stages in the development of transmitting aerials

1 inch are employed, and because the wavelength is so small the waves can be sent out in a narrow beam by a special type of aerial. The transmitting aerial is aimed directly at the receiving aerial. Using a system of these links Eurovision programmes can be sent from Moscow to London. To transmit television waves over longer distances, such as America to Europe, the waves from America are sent up to an artificial satellite which receives them, increases their strength and transmits them back to Europe.

Waves with wavelength 1 foot to 1 inch are used in radar. A beam of waves is sent out in a straight line from a rotating transmitter. If the waves meet an object such as an aeroplane a small part of the wave is reflected back to the receiving aerial. The time between the sending out of the wave and the detection of the reflected part can be accurately measured, and since we know the speed of these waves (186,000 miles per second) it is easy to calculate the distance between the aeroplane and the radar station. The direction in which the receiving aerial is pointing when it detects the reflected wave tells us the bearing of the aeroplane. This information is then displayed on a fluorescent screen similar to a television tube. Today most ships and aeroplanes carry radar to enable them to travel safely at night or when visibility is bad.

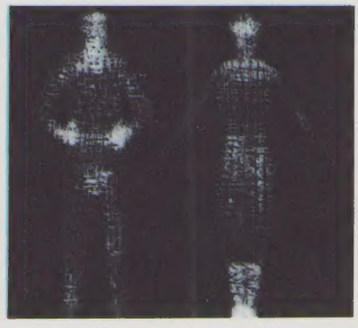
Infra-red radiation (10 octaves)

If sunlight is passed through a transparent prism made of rock salt we find that in addition to the usual visible spectrum a long strip beyond the red light is warm. This is because the rock salt is transparent to infra-red

The radar screen in a ship entering the port of New York. The position of the ship on which the radar is installed is shown by the central white dot. The irregular white marks show the shore line and other vessels. The zero on the circular scale represents North and the white line is the radar sweep

radiation (a glass prism is not). We feel infra-red rays as heat, but our eyes cannot see them; they have wavelengths from about a twentieth of an inch to 32 millionths of an inch. They are produced in large amounts by all hot materials such as electric fires and the sun, but everything which has a temperature above absolute zero (—273°C) will emit some infra-red radiation. The shorter wavelength infra-red can be detected by special photographic plates. Special instruments are used in missiles to detect the radiation coming from the hot exhaust pipes of aeroplanes and rockets. Once the missile has found the source of the radiation its electronic systems ensure that it stays pointed towards that source until it finally destroys it.

A picture taken on photographic film sensitive only to infra-red light. It shows the infra-red rays emitted by the human body at a temperature of 98·4°F



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Electromagnetic waves (part two) *Cover*
Orchids *2497*
Civil Service in Britain *2500*
Cities of Norway *2502*

contents

The Persian Wars (part two) *2504*
Respiration (part two) *2506*
The fall of Napoleon *2507*
The giraffe *2510*
Electrolysis *2512*

contents

Visible light (1 octave)

The electromagnetic waves to which our eyes are sensitive have wavelengths between 32 and 16 millionths of an inch. We see the longest waves in this octave as the colour red and the shortest waves as the colour violet. Between these two limits are all the colours of the visible spectrum.

Ultra-violet light (5 octaves)

When waves have a wavelength shorter than 16 millionths of an inch they cannot be seen by our eyes; but photographic film is very sensitive to these waves and will record them. Too much ultra-violet light is dangerous to human beings because it can damage the complex molecules in their bodies. The sun emits a large amount of ultra-violet light, but most of it is absorbed by the ozone layer in the upper atmosphere and never reaches the surface of the earth. Ultra-violet light can be produced artificially using a mercury vapour lamp. The shortest ultra-violet waves have a wavelength of about four-tenths of a millionth of an inch.

X-rays (13 octaves)

X-rays are electromagnetic waves of wavelength even shorter than ultra-violet light, ranging from four-tenths of a millionth of an inch to 40 millionths of a millionth of an inch. As the wavelength becomes shorter the X-rays can pass right through the human body and enable doctors to photograph our internal organs, and exactly locate any diseased part. Although small doses of X-rays do man no harm, prolonged or frequent doses can damage the tissues of our bodies. The shortest wavelength X-rays easily penetrate steel and it is possible to detect a crack in the centre of a weld or casting which it is impossible to see from the surface. X-rays have one more important use. Since their wavelength is similar in size to the spacing between atoms in a crystal they can be used to investigate the structure and forces in the interior of solids.

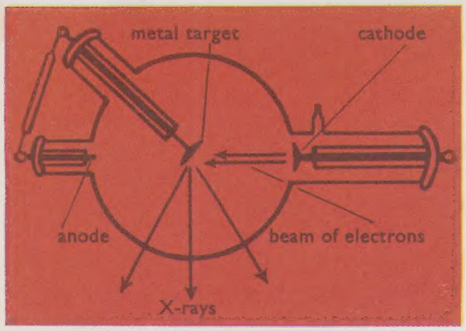
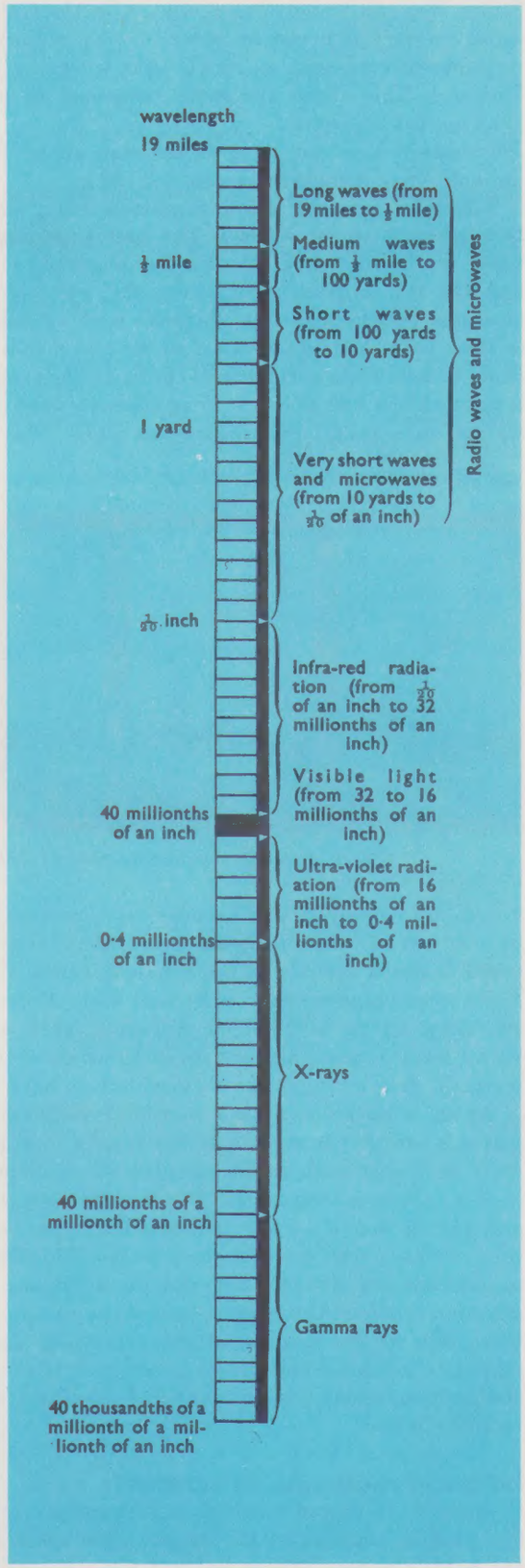


Diagram of an X-ray tube. Electrons are emitted by the cathode and accelerate towards the positive anode. Half way in their journey they hit a metal target. They knock out electrons in the target. The X-rays are emitted when the electrons in the target atoms rearrange themselves

Gamma radiation (10 octaves)

Gamma-rays have wavelengths of 40 millionths of a millionth of an inch down to about 40 thousandths of a millionth of a millionth of an inch. But nevertheless, like radio waves of wavelength 20 miles, they are still members of the family of electromagnetic waves. Their wavelength is so short and their energy so great that they can only be produced during the disintegration of the nucleus of an atom. In medicine gamma radiation is used for killing harmful cancer cells in the human body, and in industry for examining metal welds in the same way as X-rays.

We have now looked at the whole spectrum of electromagnetic waves. Although the various types seem very dissimilar they are all united. They all travel with the same velocity, they require no material medium in which to travel and they can all be described by the same mathematical theories of electromagnetic wave motion.


wavelength
19 miles
½ mile
1 yard
1/10 inch
40 millionths of an inch
0·4 millionths of an inch
40 millionths of a millionth of an inch
40 thousandths of a millionth of a millionth of an inch
Long waves (from 19 miles to ½ mile)
Medium waves (from ½ mile to 100 yards)
Short waves (from 100 yards to 10 yards)
Very short waves and microwaves (from 10 yards to 1/10 of an inch)
Radio waves and microwaves
Infra-red radiation (from 1/10 of an inch to 32 millionths of an inch)
Visible light (from 32 to 16 millionths of an inch)
Ultra-violet radiation (from 16 millionths of an inch to 0·4 millionths of an inch)
X-rays
Gamma rays

The electromagnetic spectrum divided into octaves